1.4 Post-tensioning Systems and Devices

This section covers the following topics

- Introduction
- Stages of Post-tensioning
- Advantages of Post-tensioning
- Disadvantages of Post-tensioning
- Devices
- Manufacturing of a Post-tensioned Bridge Girder

1.4.1 Introduction

Prestressing systems have developed over the years and various companies have patented their products. Detailed information of the systems is given in the product catalogues and brochures published by companies. There are general guidelines of prestressing in **Section 12** of **IS 1343: 1980**. The information given in this section is introductory in nature, with emphasis on the basic concepts of the systems.

The prestressing systems and devices are described for the two types of prestressing, pre-tensioning and post-tensioning, separately. This section covers post-tensioning. Section 1.3, "Pre-tensioning Systems and Devices", covers pre-tensioning. In post-tensioning, the tension is applied to the tendons after hardening of the concrete. The stages of post-tensioning are described next.

1.4.2 Stages of Post-tensioning

In post-tensioning systems, the ducts for the tendons (or strands) are placed along with the reinforcement before the casting of concrete. The tendons are placed in the ducts after the casting of concrete. The duct prevents contact between concrete and the tendons during the tensioning operation.

Unlike pre-tensioning, the tendons are pulled with the reaction acting against the hardened concrete.

If the ducts are filled with **grout**, then it is known as bonded post-tensioning. The grout is a neat cement paste or a sand-cement mortar containing suitable admixture. The grouting operation is discussed later in the section. The properties of grout are discussed in Section 1.6, "Concrete (Part-II)".

In unbonded post-tensioning, as the name suggests, the ducts are never grouted and the tendon is held in tension solely by the end anchorages. The following sketch shows a schematic representation of a grouted post-tensioned member. The profile of the duct depends on the support conditions. For a simply supported member, the duct has a sagging profile between the ends. For a continuous member, the duct sags in the span and hogs over the support.

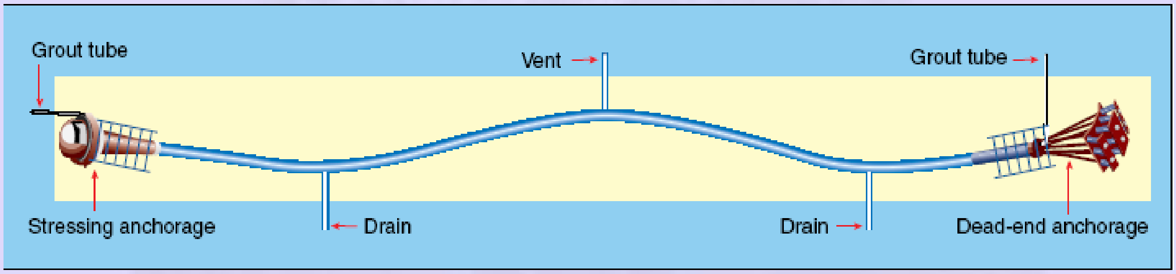


Figure 1-4.1 Post-tensioning (Reference: VSL International Ltd.)

Among the following figures, the first photograph shows the placement of ducts in a box girder of a simply supported bridge. The second photograph shows the end of the box girder after the post-tensioning of some tendons.

Figure 1-4.2 Post-tensioning ducts in a box girder

(Courtesy: Cochin Port Trust, Kerala)

Figure 1-4.3 Post-tensioning of a box girder
(Courtesy: Cochin Port Trust, Kerala)

The various stages of the post-tensioning operation are summarised as follows.

1) Casting of concrete.
2) Placement of the tendons.
3) Placement of the anchorage block and jack.
4) Applying tension to the tendons.
5) Seating of the wedges.
6) Cutting of the tendons.

The stages are shown schematically in the following figures. After anchoring a tendon at one end, the tension is applied at the other end by a jack. The tensioning of tendons and pre-compression of concrete occur simultaneously. A system of self-equilibrating forces develops after the stretching of the tendons.

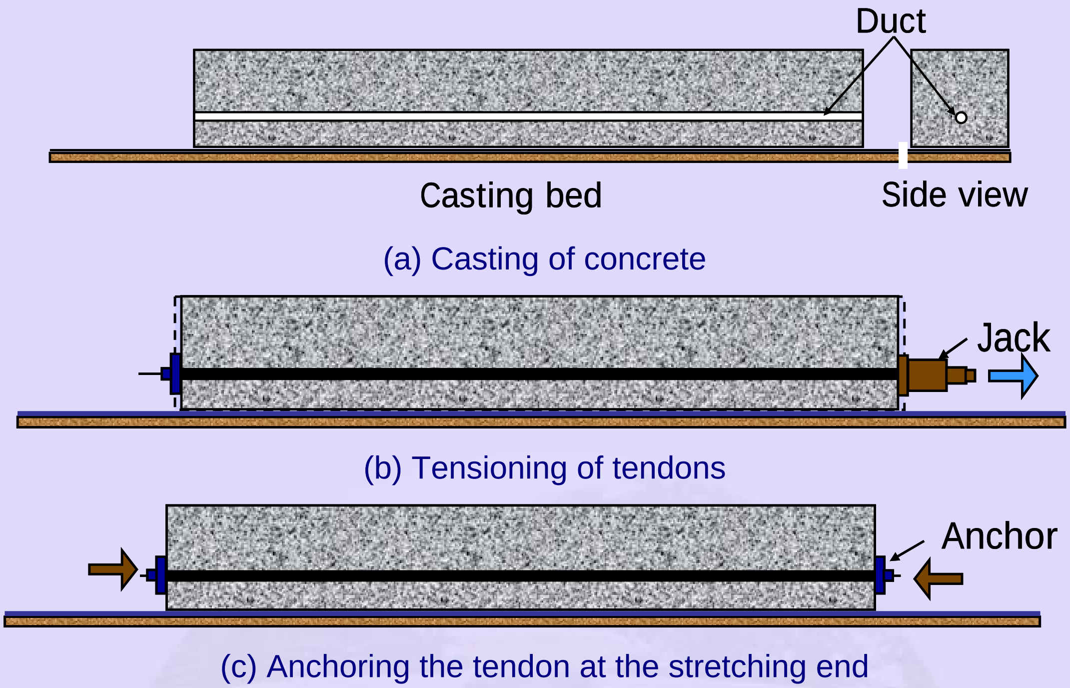


Figure 1-4.4 Stages of post-tensioning (shown in elevation)

1.4.3 Advantages of Post-tensioning

The relative advantages of post-tensioning as compared to pre-tensioning are as follows.

- Post-tensioning is suitable for heavy cast-in-place members.
- The waiting period in the casting bed is less.
- The transfer of prestress is independent of transmission length.

1.4.4 Disadvantage of Post-tensioning

The relative disadvantage of post-tensioning as compared to pre-tensioning is the requirement of anchorage device and grouting equipment.

1.4.5 Devices

The essential devices for post-tensioning are as follows.

1) Casting bed
2) Mould/Shuttering
3) Ducts

4) Anchoring devices
5) Jacks
6) Couplers (optional)
7) Grouting equipment (optional).

Casting Bed, Mould and Ducts

The following figure shows the devices.

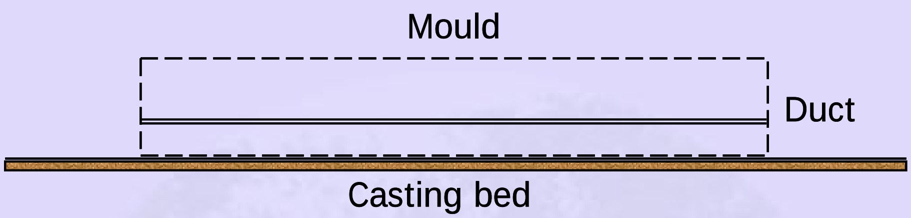


Figure 1-4.5 Casting bed, mould and duct

Anchoring Devices

In post-tensioned members the anchoring devices transfer the prestress to the concrete. The devices are based on the following principles of anchoring the tendons.

1) Wedge action
2) Direct bearing
3) Looping the wires

Wedge action

The anchoring device based on wedge action consists of an anchorage block and wedges. The strands are held by frictional grip of the wedges in the anchorage block. Some examples of systems based on the wedge-action are Freyssinet, Gifford-Udall, Anderson and Magnel-Blaton anchorages. The following figures show some patented anchoring devices.

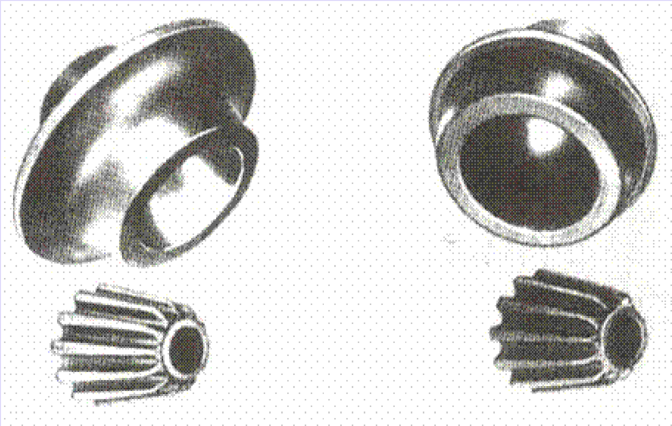


Figure 1-4.6 Freyssinet "T" system anchorage cones

(Reference: Lin, T. Y. and Burns, N. H., *Design of Prestressed Concrete Structures*)

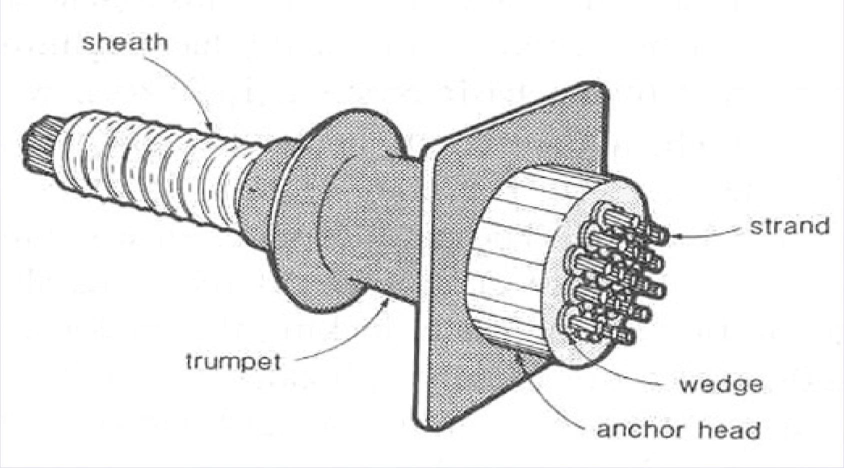


Figure 1-4.7 Anchoring devices

(Reference: Collins, M. P. and Mitchell, D., *Prestressed Concrete Structures*)

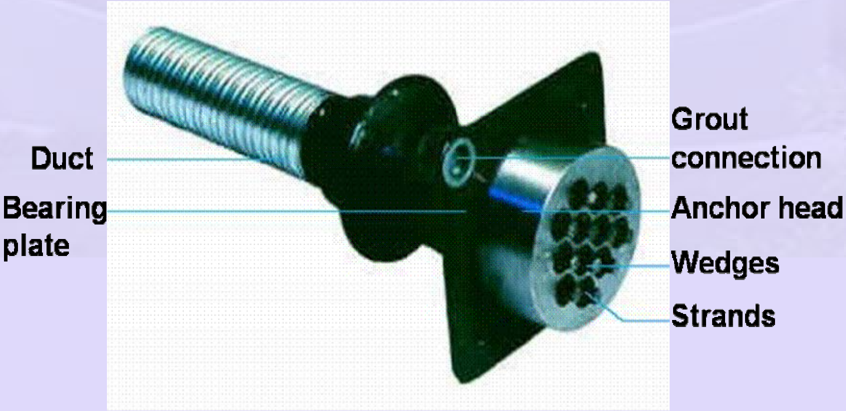


Figure 1-4.8 Anchoring devices (Reference: VSL International Ltd)

Direct bearing

The rivet or bolt heads or button heads formed at the end of the wires directly bear against a block. The B.B.R.V post-tensioning system and the Prescon system are based on this principle. The following figure shows the anchoring by direct bearing.

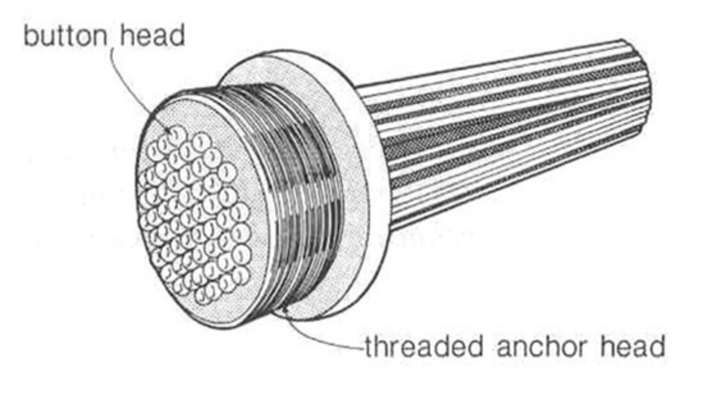


Figure 1-4.9 Anchoring with button heads

(Reference: Collins, M. P. and Mitchell, D., *Prestressed Concrete Structures*)

Looping the wires

The Baur-Leonhardt system, Leoba system and also the Dwidag single-bar anchorage system, work on this principle where the wires are looped around the concrete. The wires are looped to make a bulb. The following photo shows the anchorage by looping of the wires in a post-tensioned slab.

Figure 1-4.10 Anchorage by looping the wires in a slab

(Courtesy : VSL India Pvt. Ltd.)

The anchoring devices are tested to calculate their strength. The following photo shows the testing of an anchorage block.

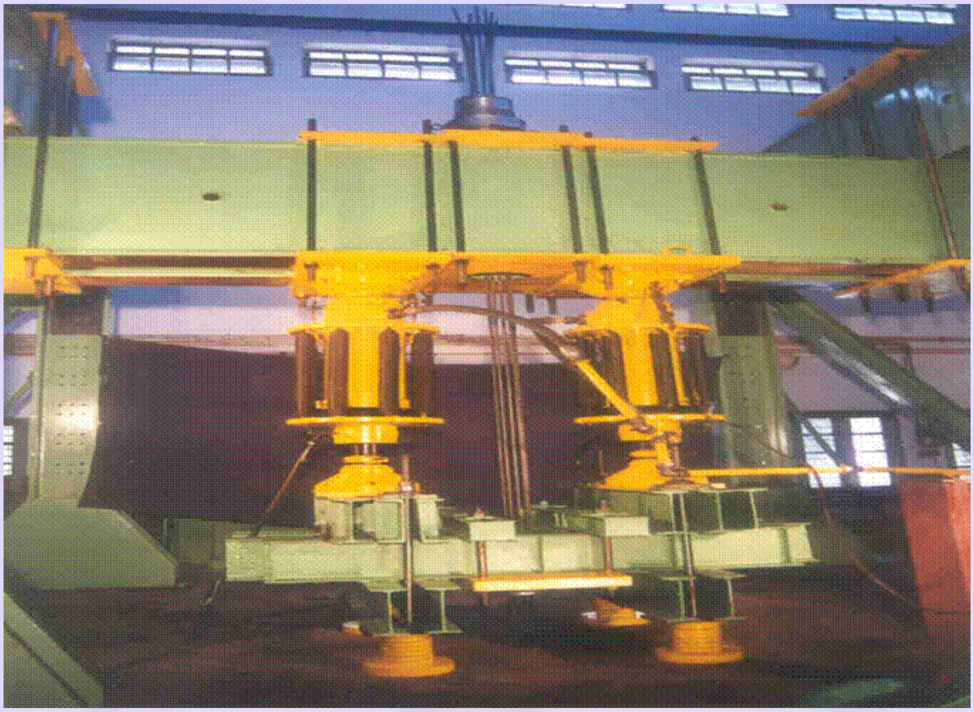
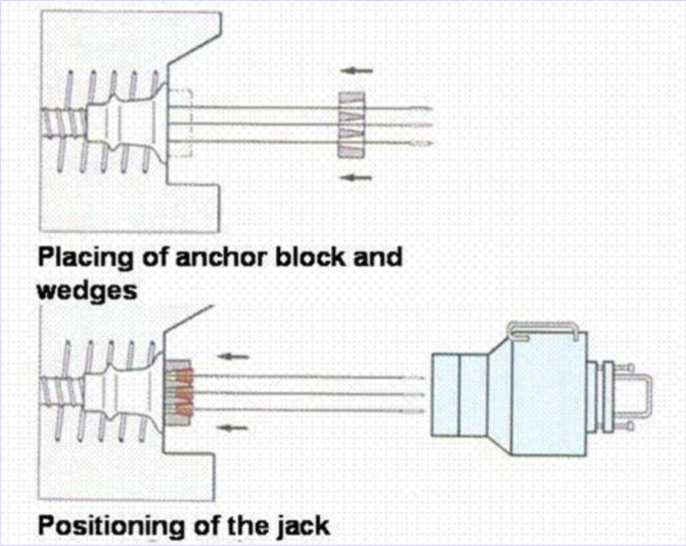


Figure 1-4.11 Testing of an anchorage device

Sequence of Anchoring

The following figures show the sequence of stressing and anchoring the strands. The photo of an anchoring device is also provided.



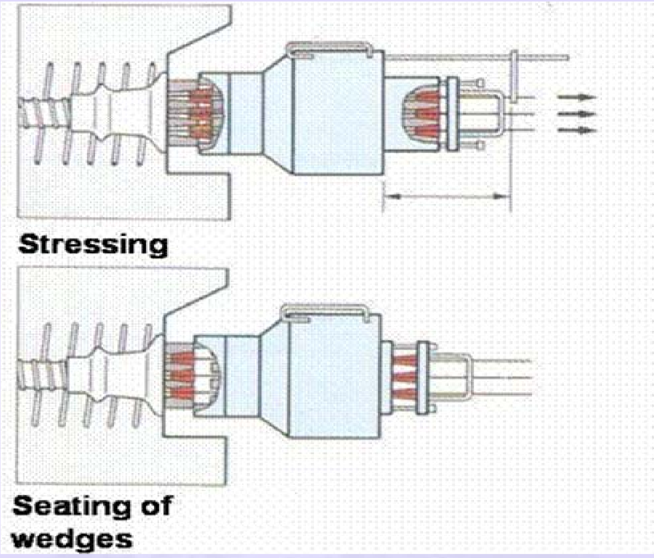


Figure 1-4.12 Sequence of anchoring

(Reference: VSL International Ltd.)

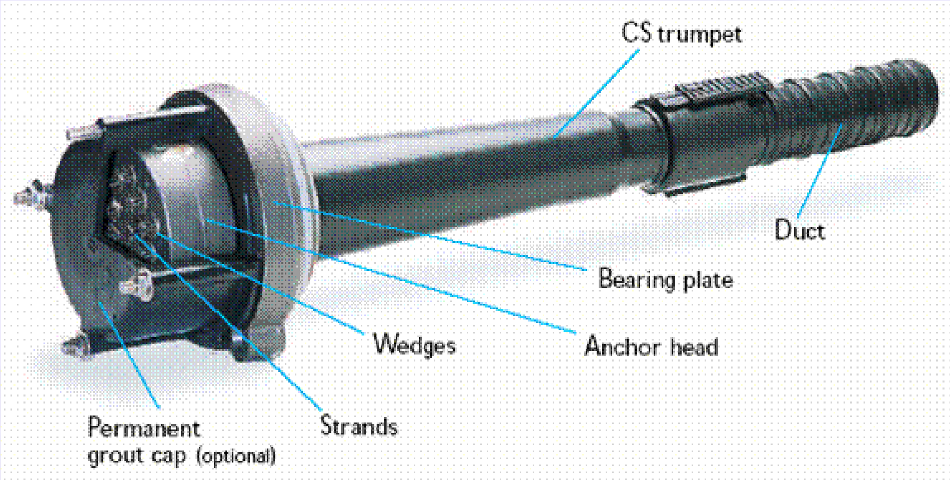


Figure 1-4.13 Final form of an anchoring device

(Reference: VSL International Ltd)

Jacks

The working of a jack and measuring the load were discussed in Section 1.3, "Pre-tensioning Systems and Devices". The following figure shows an extruded sketch of the anchoring devices.

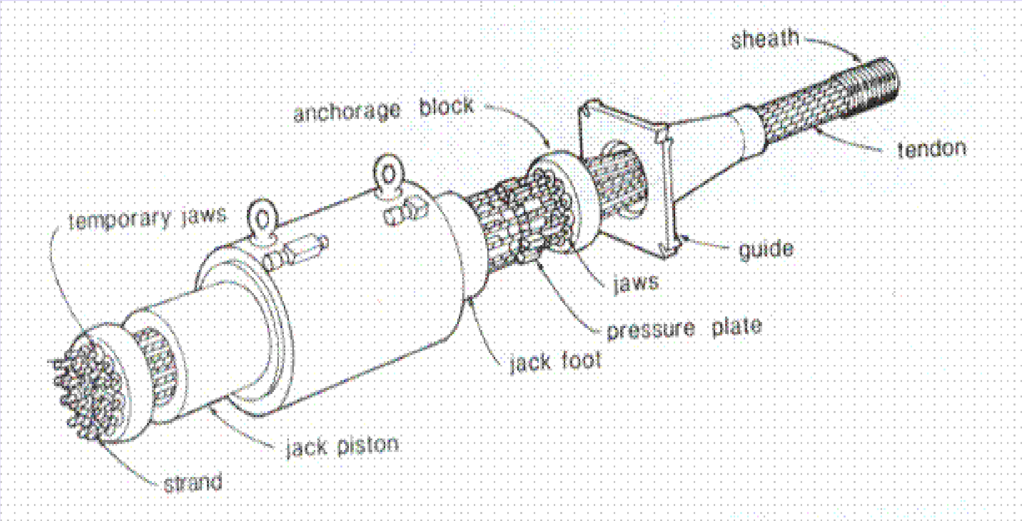


Figure 1-4.14 Jacking and anchoring with wedges

(Reference: Collins, M. P. and Mitchell, D., *Prestressed Concrete Structures*)

Couplers

The couplers are used to connect strands or bars. They are located at the junction of the members, for example at or near columns in post-tensioned slabs, on piers in post-tensioned bridge decks.

The couplers are tested to transmit the full capacity of the strands or bars. A few types of couplers are shown.

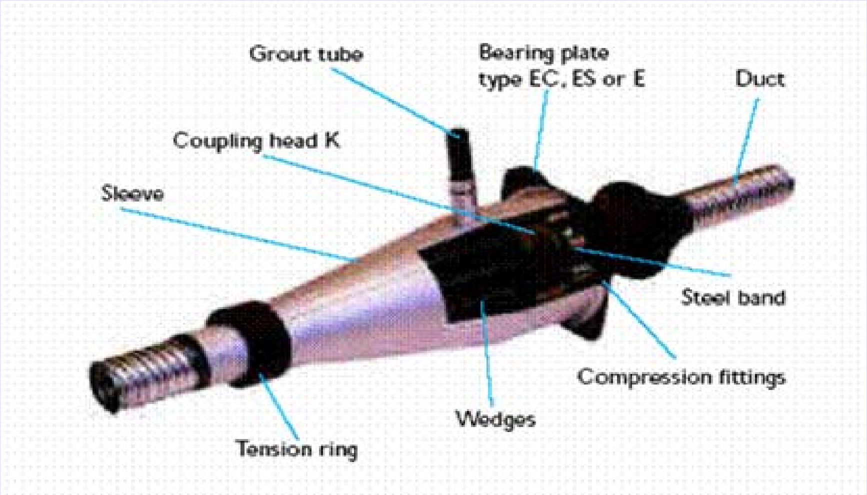


Figure 1-4.15 Coupler for strands

(Reference: VSL International Ltd)

Figure 1-4.16 Couplers for strands

(Reference: Dywidag – Systems International)

Figure 1-4.17 Couplers for strands

(Reference: Dywidag – Systems International)

Grouting

Grouting can be defined as the filling of duct, with a material that provides an anti-corrosive alkaline environment to the prestressing steel and also a strong bond between the tendon and the surrounding grout.

The major part of grout comprises of water and cement, with a water-to-cement ratio of about 0.5, together with some water-reducing admixtures, expansion agent and pozzolans. The properties of grout are discussed in Section 1.6, "Concrete (Part-II)". The following figure shows a grouting equipment, where the ingredients are mixed and the grout is pumped.

Figure 1-4.18 Grouting equipment

(Reference: Williams Form Engineering Corp.)

1.4.6 Manufacturing of Post-tensioned Bridge Girders

The following photographs show some steps in the manufacturing of a post-tensioned I-girder for a bridge (Courtesy: Larsen & Toubro). The first photo shows the fabricated steel reinforcement with the ducts for the tendons placed inside. Note the parabolic profiles of the duct for the simply supported girder. After the concrete is cast and cured to gain sufficient strength, the tendons are passed through the ducts, as shown in the second photo. The tendons are anchored at one end and stretched at the other end by a hydraulic jack. This can be observed from the third photo.

(a) Fabrication of reinforcement

(b) Placement of tendons

(c) Stretching and anchoring of tendons

Figure 1-4.19 Manufacturing of a post-tensioned bridge I-girder

The following photos show the construction of post-tensioned box girders for a bridge (Courtesy: Cochin Port Trust). The first photo shows the fabricated steel reinforcement with the ducts for the tendons placed inside. The top flange will be constructed later. The second photo shows the formwork in the pre-casting yard. The formwork for the inner sides of the webs and the flanges is yet to be placed. In the third photo a girder is being post-tensioned after adequate curing. The next photo shows a crane on a barge that transports a girder to the bridge site. The completed bridge can be seen in the last photo.

(a) Reinforcement cage for box girder

(b) Formwork for box girder

(c) Post-tensioning of box girder

(d) Transporting of box girder

(e) Completed bridge

Figure 1-4.20 Manufacturing of post-tensioned bridge box girders